FINAL REPORT

Title: Influence of past wildfires on wildfire behavior, effects & management

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List of Abbreviations/Acronyms

ERU	Ecological Response Unit
GIS	Geograhic Information System
MTBS	Monitoring Trends in Burn Severity
RdNBR	relative differenced Normalized Burn Ratio

Keywords

Arizona, burn severity, fire history, fire interactions, fire progression, fire severity, fire size, fire spread, fire suppression, fuels, MTBS, New Mexico, Southwest

Acknowledgements

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Abstract

Fire is a key driver of landscape patterns, including vegetation composition, structure, heterogeneity, and function. The interactions between fires over time and space, moderated by the fuels available to burn, have profound implications for ecosystem structure and function as well as for fire management. Vegetation mosaics are created and maintained by fire, and vegetation mosaics also affect subsequent fire patterns. Fire interactions can be reburns, if fires burn over the same area burned in previous wildfire. Fire interactions can also occur if a previous fire prevents the growth of a subsequent fire. In these cases the previous wildfire may be limiting the spread of the subsequent fire by acting as a fuel break. In this study, we focused on A) the role of previous wildfires and roads in limiting wildfire growth and influencing the pattern of fire at a regional scale, and B) the influence of past wildfire severity on subsequent fire severity in reburns. In Part A, using fire perimeter data from the U.S. Southwest, we asked 1) To what degree do previous wildfires and roads limit the spread of subsequent fires? 2) What are the temporal patterns in fire perimeter limitations, in terms of time-since-fire and stability of patterns over time? 3) Do limitations to fire spread differ across land ownership, topographic variables, or vegetation patterns? We found a limited but significant impact of previous fires and roads in limiting subsequent fire progression. Of fires that intersected previous wildfires, an average of 10.5% of their perimeters aligned with the previous wildfire perimeter, compared to 4.2% when fires were randomly shifted on the landscape. The average percentage of fire perimeters that aligned with roads was 20.4%, compared to 10.3% when fires were randomly shifted. More than half of fire-fire alignments occurred when time since the previous fire was 5 years or less, and fire-fire alignments have grown over time while fire-road alignments have been stable since the late 1980s. Fire-fire alignments varied by land ownership, National Forest, slope, and vegetation diversity. In Part B, we asked 4) To what degree do previous fires influence subsequent fire severity? 5) Does previous wildfire influence on fire severity vary over time? We found that on average, RdNBR values were lower with increasing times burned. However, the averages masked an important point: the subset of points that reburned had lower first-fire severity than all points on average. Thus, fire severity increased in almost as many points as it decreased in subsequent burns. The change in severity from one fire to the next varied by time since fire; on average, subsequent fire severity was less than previous fire severity when time since fire was low. In addition, absolute fire severity in subsequent fires tended to increase with time since the previous fire. As more fires burn, fire interactions are likely to increase, and previous fires may have more opportunity to act as fuel breaks, control points, or fuel reduction treatments for subsequent fires.

Objectives

Do wildfires act as fuel treatments by affecting subsequent wildfire behavior and effects? Our objectives were to: A) determine the role of previous wildfires and roads in limiting wildfire growth and influencing the pattern of fire at a regional scale, and B) determine to what degree past wildfires have resulted in conditions that can be considered effective fuel treatments, measured by subsequent fire severity. This is important information for fire managers because the fuel changes caused by past wildfires may have implications for wildfire management prior to and during fire events. The fuel changes caused by past wildfires may result in smaller subsequent fires, lower (or higher) subsequent fire severity, and more options for managing a fire start. In addition, exploring these themes can help us better understand how fires and the landscapes they burn interact over time and space.

Background

Fire is a key driver of landscape patterns, including vegetation composition, structure, heterogeneity, and function. The interactions between fires over time and space, moderated by the type and amount of fuel available to burn, have profound implications for ecosystem structure and function as well as for fire management. Vegetation mosaics are created and maintained by fire, and vegetation mosaics also affect subsequent fire patterns (Turner 1989, Peterson 2002). Fire interactions can be reburns, if fires burn over the same area burned in previous wildfire (e.g., Holden et al. 2010). Fire interactions can also occur if a previous fire prevents the growth of a subsequent fire (Graham 2003, Price and Bradstock 2010, Parks et al. 2015). In these cases the previous wildfire may be limiting the spread of the subsequent fire by acting as a fuel break.

Several studies have examined the effects of previous fire on subsequent fire severity. Many have found that higher severity in an initial fire is correlated with higher severity in subsequent fires (Holden et al. 2010, van Wagtendonk et al. 2012, Parks et al. 2014). Coppoletta et al. (2016) linked this phenomenon to increased shrubs and snags in high-severity burned areas, which provide fuel for subsequent higher-severity fires. Conversely, low-severity reburns have been shown to be more likely when the area had previously burned with low severity (Holden et al. 2010). There are also temporal considerations to wildfire severity interactions. Nine years was a threshold value for whether subsequent fires would reburn an area in the Yosemite ecosystem (Collins et al. 2009). Burn severity was reduced in areas that had burned up to 22 years previously in a study by Parks et al. (2013).

An increasing amount of research has been carried out on fire severity and fire effects, but the factors controlling the spatial patterns of fire perimeters have received less attention until recently (Prichard et al. 2017). The perimeters of fires are important because of the interplay between pattern and process at the landscape scale (Krawchuck et al. 2016). In addition, understanding whether previous fires can be regarded as fuel treatments is useful for fire and forest managers in planning fuel treatments as well as during active wildfire management (Prichard et al. 2017).

Other landscape features, commonly roads, can also either act as fuel breaks or be used by fire managers as fire lines or areas from which to initiate fire suppression actions such as burning out of fuels ahead of the wildfire. Roads ecologically affect approximately 15-20% of US land area by altering wildlife behavior and movement, erosion and hydrology, and ecological processes such as fire (Forman and Alexander 1998, Aldersley et al. 2011). Human-caused fire ignitions tend to occur near roads (Narayanaraj and Wimberly 2012) but roads also serve as convenient fire breaks and allow firefighters to move through the landscape to carry out management activities.

Focusing on fire perimeters, or specifically where fires stop burning, lends insight into both ecological aspects of fire and contemporary fire management. Previous studies have examined the effectiveness of previous wildfires in limiting subsequent wildfire growth in wilderness areas or National Parks where roads are less common and fire suppression strategies are less aggressive (Collins et al. 2009, Teske et al. 2012, Parks et al. 2015). These studies provide a better understanding of wildfire behavior and limits to spread without heavy human intervention. Other studies have evaluated fuel breaks (Syphard et al. 2011) or roads (Narayanaraj and Wimberly 2011), which provide evidence of the effectiveness of human-built features and management actions in preventing fire growth.

We were interested in the importance of both previous wildfires and roads in influencing fire perimeters over time at the regional scale and also the importance of previous wildfire in affecting subsequent fire severity. Previous assessments of the effects of past wildfires have been relatively limited to case studies, especially in areas such as National Parks or wilderness where management policies favored substantial fire use (e.g., Rollins *et al.* 2002, Collins *et al.* 2009). Our approach was to concentrate on the effects of previous fire on subsequent fire size and severity, not only in wilderness areas but across the southwestern United States. In this region, starting in the late nineteenth and continuing through much of the twentieth century, relatively little fire activity was recorded due to a combination of logging, grazing, and fire suppression (Covington and Moore 1994, Swetnam and Baisan 1996). However, in recent decades more fires and larger fires have been burning (Westerling et al. 2006, Dillon et al. 2011, Poling 2016), giving the opportunity for fires to interact on the landscape. In addition, the Southwest has a variety of vegetation types across a strong elevational gradient, a diversity of land ownership, and an available comprehensive dataset of fire perimeters. In Part A, on limitations to fire spread, our questions were: 1) To what degree do previous wildfires and roads limit the spread of subsequent fires? 2) What are the temporal patterns in fire perimeter limitations, in terms of time-since-fire and stability of patterns over time? 3) Do limitations to fire spread differ across land ownership, topographic variables, or vegetation patterns? In Part B, we asked 4) To what degree do previous fires influence subsequent fire severity? 5) Does previous wildfire influence on fire severity vary over time?

Materials and Methods

Our study area was Arizona and New Mexico in the U.S. Southwest. Fires are common in this region and vegetation ranges from desert to high-elevation spruce-fir forests. We used Monitoring Trends in Burn Severity (MTBS) data in our analysis (Eidenshink et al. 2007).

MTBS data consists of fire perimeters and fire severity raster datasets for large wildfires (over 405 ha in the western United States). MTBS data is available region-wide, has high spatial resolution (30 m), and is available from 1984 to present (Eidenshink et al. 2007). The comprehensive nature of the dataset allows analysis of fire interactions at a regional scale over several decades.

In Part A, to examine the role of previous fires in limiting the growth of subsequent fires using fire perimeter information, we selected the fire perimeters for all fires in Arizona and New Mexico between 1984 (the earliest available data) to 2014 from the MTBS database and defined the outside perimeter of each fire as our unit of analysis. To quantify the extent of fire perimeter alignments, we used a GIS to manage and analyze spatial patterns in the MTBS fire perimeters. In chronological order, each fire was first examined as a "subsequent" fire: did the subsequent fire touch a previous fire? Then each fire became a "previous" fire, meaning it was there on the landscape for a subsequent fire to encounter. To account for error in mapping, we buffered each previous fire 150 m inside and outside the perimeter, for a 300-m-wide perimeter band. For each subsequent fire, we determined the distance and proportion of its perimeter that "aligned with" (fell within) the previous fire's 300-m-wide perimeter band. We excluded situations in which perimeters aligned but the subsequent fire was inside the previous fire; in these situations, the previous fire did not prevent the subsequent fire's growth. We created a road coverage from Forest Service and ESRI GIS layers and buffered the roads 60 m on each side, for 120 m total road widths. We determined the distance and proportion of fire perimeters that aligned with the buffered roads (Fig. 1).

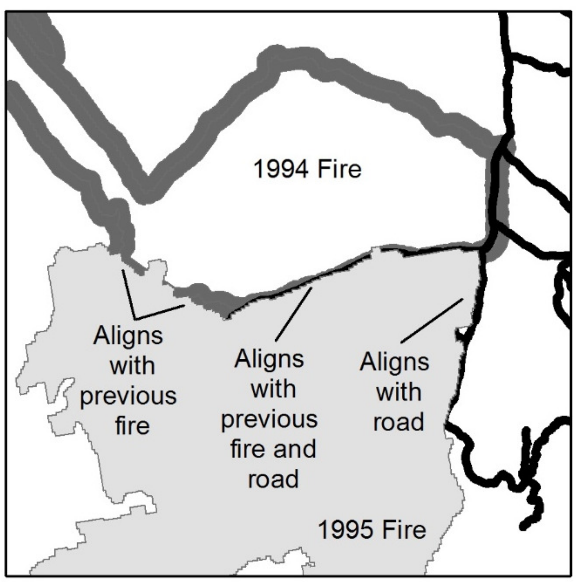


Figure 1. Example of a 1995 fire burning up to a 1994 fire. The 1994 fire's perimeter is buffered 150 m inside and outside for a 300-m total perimeter band. Roads are buffered 60 m on each side for a 120-m total road width. Segments of the 1995 fire align (i.e., the perimeter falls within the buffers) with (1) the previous fire only, (2) the fire and a road, and (3) a road only.

Because some fires were isolated and never touched another previous fire (i.e., never had a chance to interact with a previous fire perimeter), we also calculated distances and proportions of fire perimeter alignments only for fires that did encounter a previous fire. Finally, we repeated all calculations for each fire sequentially after randomly rotating and moving the fire perimeter a random distance and direction. We shifted each fire a maximum of 10 km from its original location to avoid moving a fire to a completely different vegetation type or topographic setting. We then tested differences between proportions of fire perimeters that aligned with previous fires, roads, and both between actual locations and randomly shifted locations using two-sample Kolmogorov-Smirnov tests for the equality of distributions (Massey 1951).

To evaluate time since fire and patterns of fire perimeter alignments over time, we divided the actual and the randomly shifted fire perimeters into segments according to land ownership and whether the segments aligned with roads or previous fires. Each segment represented a unique combination of fire, road, ownership and previous fire status. We then calculated lengths and proportions of fire perimeters that aligned with previous fires, roads, or neither according to ownership. We also summarized statistics on time since fire and year of subsequent fire for each fire alignment.

Finally, using each line segment from the previous analysis, we placed sample points at the beginning and end of the segment, as well as at 500-m intervals along the line. At each of these sample points, we obtained slope, aspect, topographic position index, and a Shannon's diversity index of vegetation diversity from raster datasets. The topographic position index was calculated as the elevation at every grid cell minus the average elevation in the 0.25-mile radius neighborhood. The diversity index was calculated using a 5-cell radius circle (150m), with the following four simple landcover classes from LANDFIRE: 1) developed, barren or no data, 2) sparse, shrub, herb or agriculture, 3) tree, or 4) water. Values from all raster datasets were obtained at each point using bilinear interpolation.

For Part B, we selected all fires from the MTBS data access website in Arizona and New Mexico that burned between 1984 and 2013 on Forest Service land. Using ArcGIS10.3, we mapped all areas of overlap between the fires. We excluded areas within 100 m of the edge in each overlap to account for mapping error and then selected areas of overlap that were ≥ 10 ha. We placed random points in these areas of overlap, requiring that points be separated by ≥ 200 m to reduce autocorrelation. We then extracted RdNBR values for each fire that had burned at each point, using bilinear interpolation. RdNBR is a measure of severity calculated from pre- and post-fire Landsat satellite imagery, relativized by pre-fire conditions (Miller and Thode 2007). We also extracted values at each point from LANDFIRE coverages, including aspect, elevation, and slope (LANDFIRE 2016, www.landfire.gov). Finally, we extracted Ecological Response Unit (ERU) values (Wahlberg et al. 2013).

Results and Discussion

In Part A, a total of 1,615 fires were available to use in our analysis. The combined perimeter of all fires was 53,067 km. Most fires (1,082) never encountered another previous fire, but 533 fires did encounter a previous fire. A total of 1,778 km of fire perimeter aligned only with previous fire perimeters (not roads), 10,360 km aligned only with roads (not fires), and 855 km aligned with both roads and fires.

1) To what degree do previous wildfires and roads limit the spread of subsequent fires?

Fire perimeters aligned with previous fires only, roads only, and fires and roads significantly more on actual fire perimeters than on randomly shifted perimeters (Fig. 2). On average across all fires (N = 1615), 0.035 of fire perimeters aligned with previous fire perimeters (not roads), but the proportion was 0.019 when fire perimeters were rotated and randomly moved (K-S test D = 0.0656, p = 0.001). Of those fires that actually encountered a previous fire and therefore had the opportunity to align with a previous fire (perimeters touched somewhere; N = 533), 0.105 of the perimeters aligned with previous fire perimeters compared with 0.040 when fires were randomly shifted (K-S test D = 0.4634, p << .001). The average proportion of fire perimeters that aligned with roads only (not fires) was 0.204, compared to 0.103 when fires were randomly shifted (K-S test D = 0.3133, p << .001). Finally, the average proportion of fire perimeters that aligned with both previous fires and roads was 0.017, compared to 0.003 when fires were randomly shifted (K-S test D = 0.1177, p << .001).

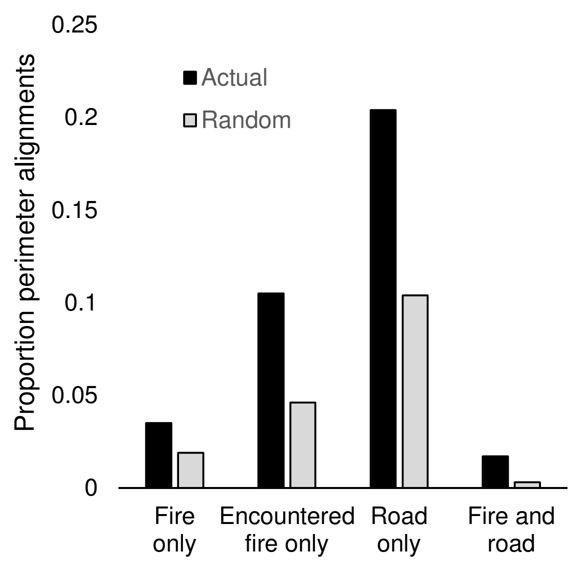


Figure 2. Mean proportion of all fire perimeters that aligned with only previous fires, only previous fires for the subset of fires that did encounter a previous fire, only roads, or both previous fires and roads. Black bars indicate actual proportions and gray bars indicate proportions when fires were randomly spatially shifted and rotated. All pairs of distributions (actual vs. randomly shifted) were significantly different.

2) What are the temporal patterns in fire perimeter limitations, in terms of time-since-fire and stability of patterns over time?

More than 50% of fire-fire alignments occurred when time-since-fire was 5 years or less. The most common time-since-fire for fire-only alignments was 1 year (Fig. 3). As for trends over time, we found that there is a strong linear trend over time toward a higher proportion of fire-fire perimeter alignments, with some years standing out (R^2 = 0.55, Fig. 4). Certainly this trend is related to the fact that our dataset started in 1984 and so we are missing early fire-fire alignments. However, since large fires have also increased in the past few decades, we are likely also seeing that as more fires burn, the more fire interactions there will be, at least until some level of saturation is hit in the future. Finally, we found that road-fire alignments have been fairly stable since approximately 1988.

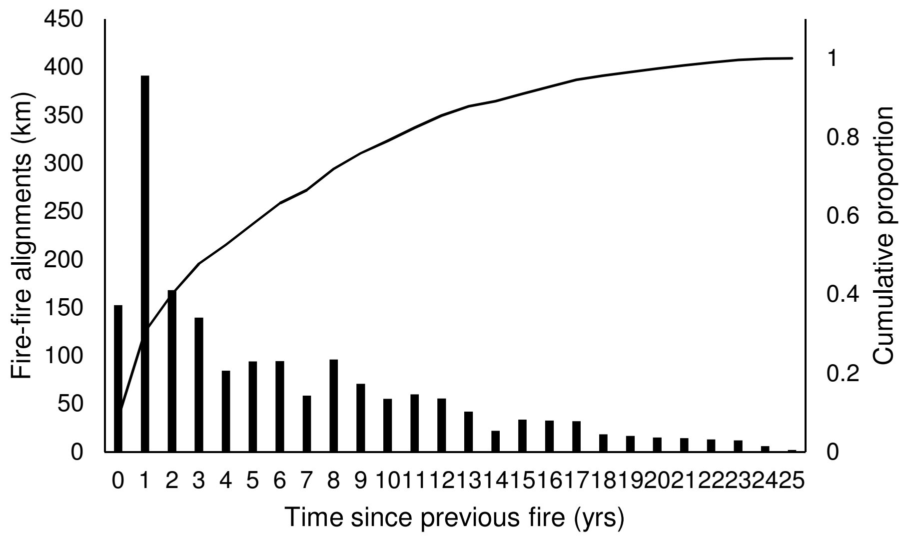


Figure 3. Kilometers of fire-fire alignments by time since fire (bars). Line represents cumulative proportion of values in each year. Approximately 58% of fire-fire alignments occur within 5 years or less of the previous fire.

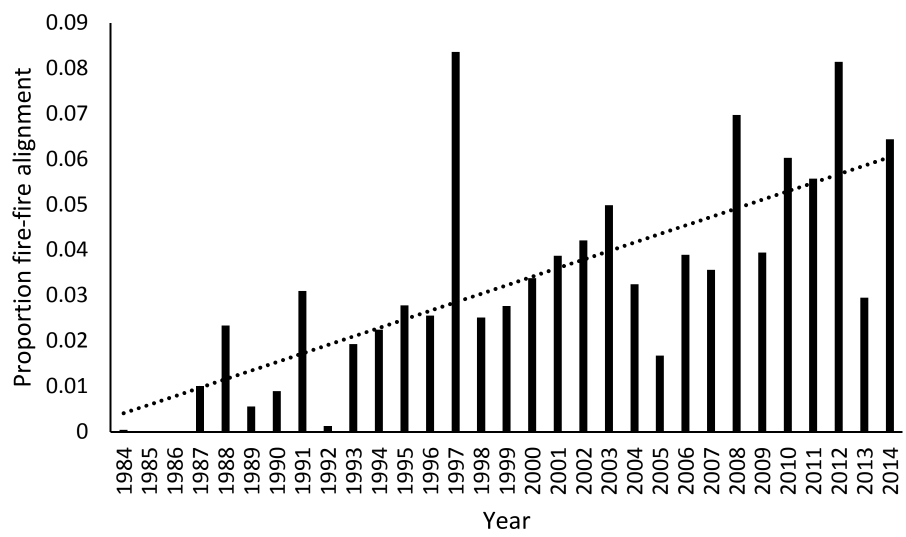


Figure 4. Proportion of fire perimeters that aligned with previous fire perimeters, by year of alignment. Trend line shown as dotted line (R^2 = 0.55). This is certainly partly explained by the fact that our dataset began in 1984, but also shows that as more fires burn on the landscape,

they have more opportunities to interact.

3) Do limitations to fire spread differ across land ownership, topographic variables, or vegetation patterns?

Fire-fire and fire-road alignments varied greatly across ownership, vegetation, and by individual National Forests in the Southwest. In terms of ownership, the Forest Service had by far the greatest total perimeter burned, but the U.S. Fish and Wildlife Service had nearly 4 times the proportion of fire-fire alignments (Table 1).

Table 1. Total fire perimeter burned, proportion fire-fire alignments, and proportion road alignments by land ownership, 1984-2014.

Ownership	Total Perimeter Burned (km)	Proportion Fire-Fire Alignments	Proportion Road Alignments
Bureau of Indian Affairs	4959	0.03	0.18
Bureau of Land Management	7485	0.03	0.13
Department of Defense	1815	0.02	0.16
Forest Service	18954	0.04	0.23
National Park Service	1715	0.06	0.11
Non-Governmental Organization	1149	0.09	0.15
Private	441	0.03	0.21
State Department of Land	1476	0.01	0.10
State Land Board	3101	0.03	0.22
U.S. Fish & Wildlife Service	1268	0.14	0.14

A pattern emerged across the 11 National Forests in the region; fire-fire alignments increased with total perimeter length on each Forest. The Carson National Forest had 0 fire-only perimeters, while the Gila National Forest, which contains a large amount of wilderness area, had the highest proportion of fire perimeter alignments at 0.053.

In terms of topography, slope was significantly different between road-only alignments and fire-only alignments (K-S test $D = 0.22005$, $p << .001$). Road-only alignments tended to be on less steep slopes while fire-only alignments had a flatter distribution and occurred more often on steeper slopes (Fig. 5).

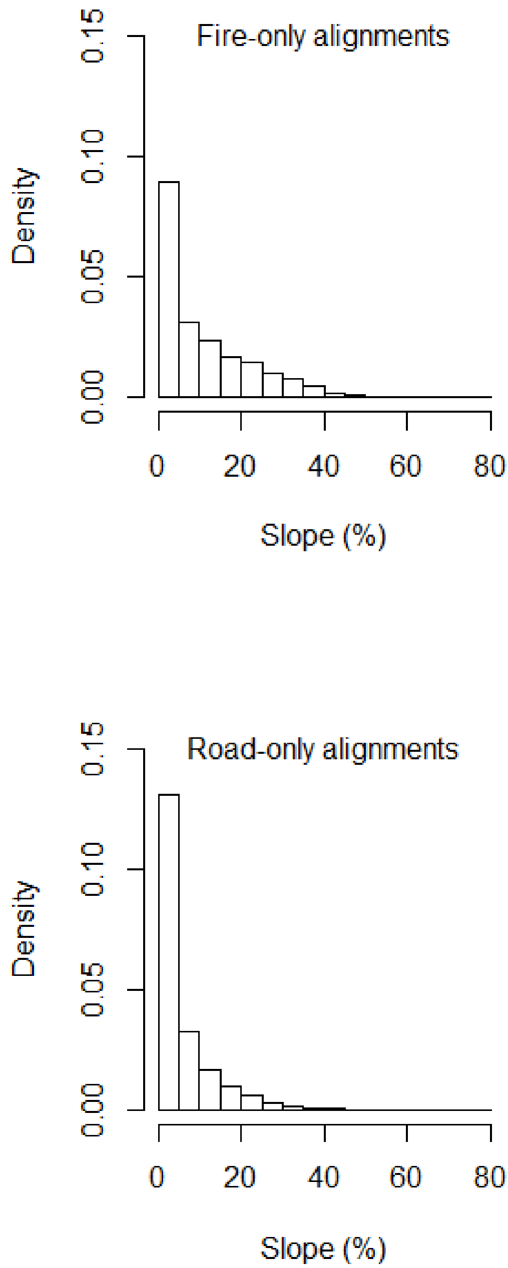


Figure 5. Distribution of sampled slope values for fire-only alignments (top) and road-only alignments (bottom). Fire-only alignments had a distribution that included steeper slopes, whereas road-only alignments were more concentrated in flatter areas.

In a comparison of topographic complexity index, fire perimeters were more likely in all cases (fire alignments only, road alignments only, fire and road alignments and no alignments) to be located in valleys or on ridges than randomly positioned fire perimeters. Also, all fire perimeters were more likely to be located in valleys than ridges. Vegetation diversity was likely to be higher at all actual fire perimeters (aligned with fires, roads, fires and roads, or nothing) than at random fire perimeters.

Our results are similar to studies elsewhere that showed a small effect of previous fires in limiting subsequent fire growth but a larger effect of roads in stopping wildfires. Proportions of fire perimeters that aligned with previous fire perimeters were low in our study area, but comparable to eastern Australia, where 10.7% of wildfires that encountered a previous wildfire within 5 years stopped at the previous fire perimeter (Price and Bradstock 2010). In our study, roads were more likely than previous fire perimeters to be aligned with fire perimeters, which is similar to what Narayanaraj and Wimberly (2011) found in central Washington. In that study, distance to roads was the most important factor predicting fire perimeters of several fires.

In terms of temporal patterns, the second question, we found that fire perimeters aligned most often when time since the previous fire was low; more than 50% of alignments occurred when the time gap was 5 years or less, and the most common time gap was one year. We even found some fire perimeter alignments from within the same year. Parks et al. (2015) found that 6 years was approximately the longest a previous fire would act as an effective fuel break in the Gila and Aldo Leopold Wilderness. A review by Prichard et al. (2017) reported North American coniferous forests showed evidence of serving as effective barriers to subsequent fire spread up to 6 years post-fire in the Southwest, and 14-35 years in the Rocky Mountains and interior Pacific Northwest.

Fire management policies have evolved substantially over the past several decades (Stephens et al. 2016). During much of the twentieth century, managers attempted to suppress most fires at the smallest possible size, the "10 a.m. policy" (Pyne 1982). Changes in the study period include increasing acceptance of the ecological role of fire (USDA-USDI 2009), an increase in managed fires, coupled with a containment strategy that minimizes direct attack in favor of allowing fire to move to well-defended, safe lines, typically reinforced by burning out adjacent fuels (Stephens et al. 2016). These changes have likely contributed to increased area burned relative to area burned if the "10 a.m. policy" were still in effect. As fire management policies, landscape fuel continuity, and warming climate interact in the coming decades, it is likely that trends in average fire size, severity, and fire perimeter spatial patterns will continue to shift.

In the third research question on ownership, terrain, and vegetation, we found that Forest Service lands had the greatest amount of burned perimeter, as expected given the predominance of Forest Service ownership of mid- and high-elevation southwestern wildlands. The relationship between total perimeter and fire-fire alignments was very clear across National Forests, with more fire leading to more fire-fire interactions. Fire perimeter alignments tended to be located on steeper slopes than fire-road alignments, suggesting that although fire-fire alignments are proportionally small, previous fires could be useful fuel breaks in steeper terrain. Fire perimeters were more likely to be located in areas with higher vegetation diversity, compared to randomly shifted fires. We interpret this to mean that fire perimeters are more likely to be located in ecotones, where forests meet grasslands, for example.

Limitations of this study included the fact that we focused on fires over 405 ha in size, so our estimates of fire-fire alignments are conservative. However, by focusing on large fires we accounted for the majority of area burned and fire perimeter length so adding small fires likely would not change the results substantially. We did not study interior perimeters (unburned patches inside fire perimeters, also called fire refugia, e.g., Haire et al. 2017), so the present analysis also gives a conservative estimate of fire-fire alignments (Kolden et al. 2012). We also did not include weather variables given our fire sample size of 1615 fires over 31 years. However, multiple studies have shown that weather can override the moderating or limiting effect of previous fires (Parks et al. 2015, Price et al. 2015). Finally, since we focused on perimeter alignments, it's possible that previous wildfires are behaving as fuel breaks more often than we calculated, if subsequent fires were more likely to slow down and stop somewhere inside a previous burn scar. For example, Teske et al. (2012) found that most reburned areas in wilderness areas were small, suggesting that although subsequent fires may not stop precisely at a previous fire perimeter, the previous fire may still act as a fuel treatment by keeping subsequent fire growth to a minimum.

It is not surprising that fire perimeter alignments were somewhat low; the likelihood of fire encounters increase as more fires burn in a region (Price et al. 2015), and although the incidence of large fires in our study area has been increasing in the Southwest, the region is not saturated with previous burn scars. As more fires burn, fire interaction patterns will change because they will have more opportunity to intersect and interact with previous wildfires, and fire perimeter alignments are likely to increase.

In Part B, examining fire severity in reburns in the Southwest, there were 552 fires available to use in our analysis. After creating random points in areas of fire overlap, we had a sample size of 83,893 points to use in sampling fire severity and landscape characteristics.

4) To what degree do previous fires influence subsequent fire severity?

We found that on average, RdNBR values were lower with increasing times burned (Fig. 6). However, the averages mask an important point: the subset of points that reburned had lower first-fire severity than all points on average (Figs. 6, 7). Looking by point, fire severity from the first to the second burn increased in almost as many points as it decreased (Table 2). However, by the fourth burn, almost twice as many points decreased in severity as increased (Table 2).

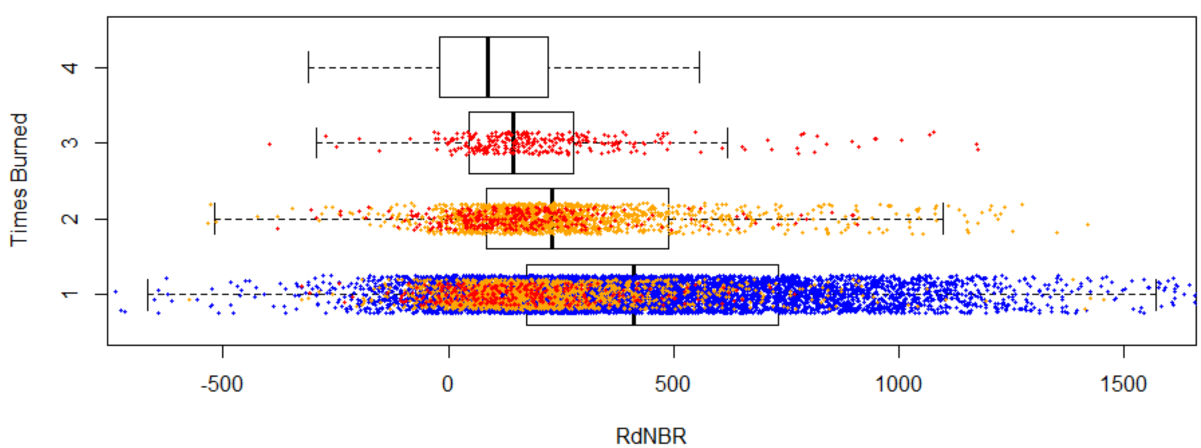


Figure 6. RdNBR values at points that burned 1, 2, 3, and four times. Blue dots represent the points that burned twice, orange dots represent the points that burned 3 times, and red dots represent the points that burned 4 times.

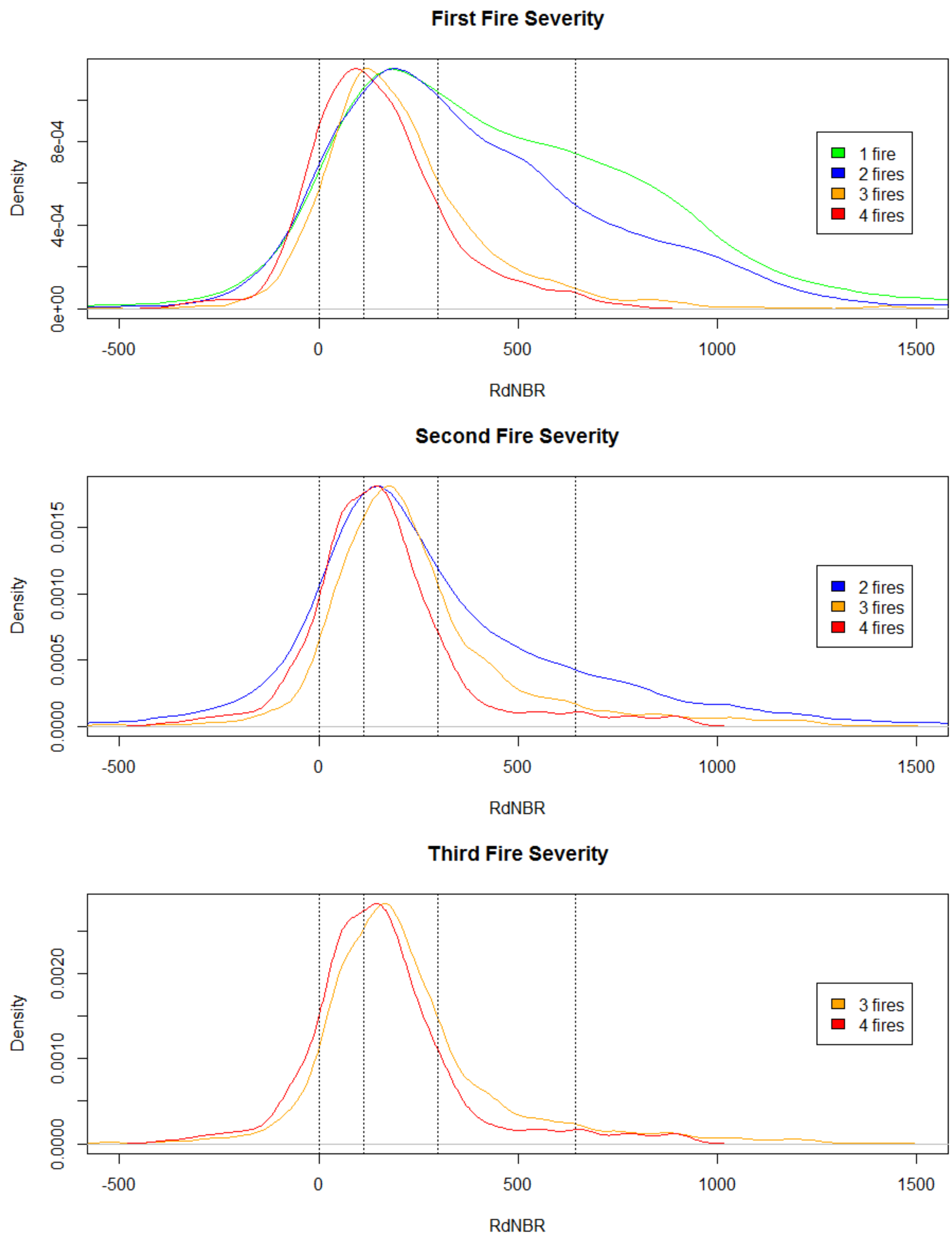


Figure 7. Top panel: distribution of first-fire burn severity for points that burned 1, 2, 3, and 4 times. Middle panel: distribution of second-fire burn severity for points that burned 2, 3, and 4 times. Bottom panel: distribution of third-fire burn severity. Points that reburned had lower

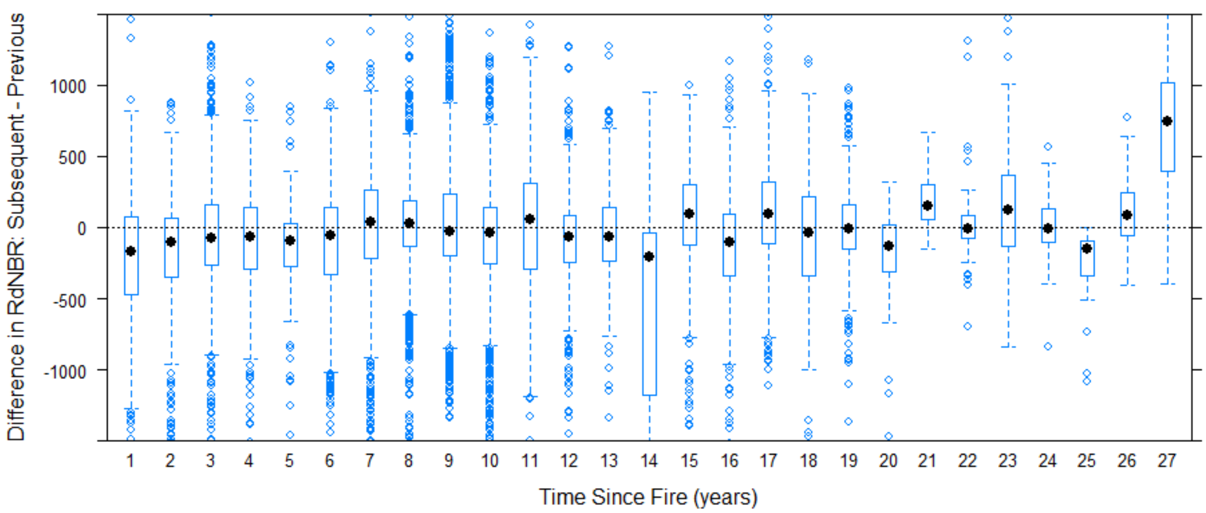
initial severity than the entire population of points. Vertical dashed lines show, for reference, cut-offs for (0 to 112) unburned, (113 to 297) low severity, (298 to 644) moderate severity and (>645) high-severity.

Table 2. Count of points and percent (in parenthesis) in which burn severity increased and decreased from first to second, second to third, and third to fourth burn.

	Increased severity	Decreased severity
First to second	4371 (47%)	4838 (53%)
Second to third	763 (43%)	996 (57%)
Third to fourth	109 (36%)	191 (64%)

5) Does previous wildfire influence on fire severity vary over time?

The change in severity from one fire to the next varied by time since fire (Fig. 8, top panel). When time since fire was six years or less, average differences in fire severity show the subsequent fire having lower severity than the previous fire. After six years, results are variable. This may be due to the large variation seen in the data and could be a reflection of the vegetation at the time of the subsequent burn. Recovery of some systems (grasses and sprouting species) would be quicker. Absolute fire severity also tended to increase with time since fire (Fig. 8, bottom panel).



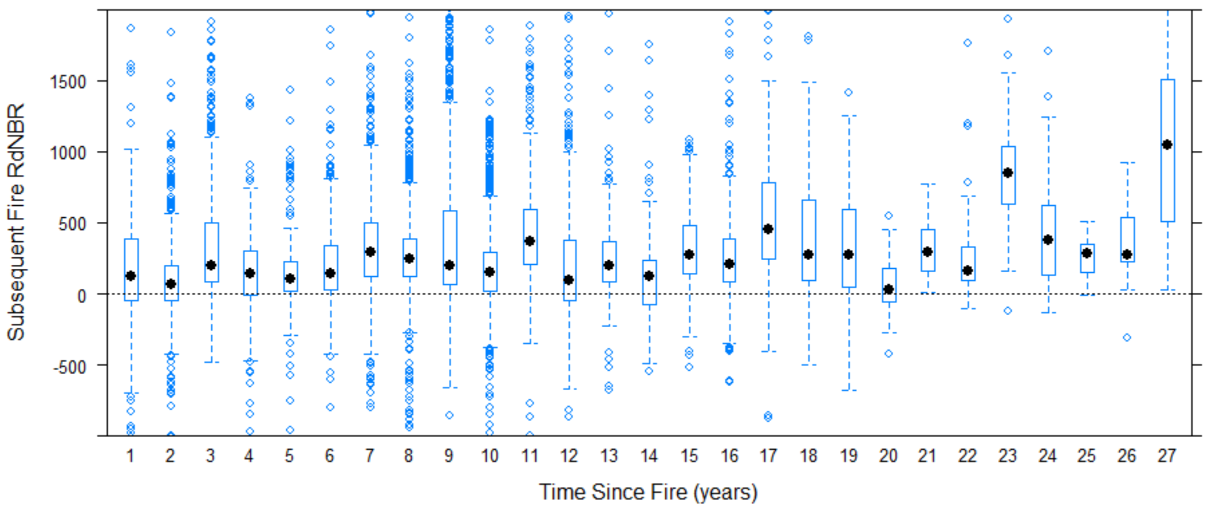


Figure 8. Top panel: Difference in fire severity between subsequent and previous fire, by time since fire. Bottom panel: Fire severity at points that burned 2, 3, or 4 times, by time since fire.

Key Findings

We found that subsequent fire perimeters did often align with previous fire perimeters in our study area, suggesting that the pattern of previous wildfires influenced the process of fire and, therefore, subsequent fire patterns. However, fire-fire alignments were relatively limited. Even when we focused the analysis on fires that touched a previous fire perimeter somewhere and therefore had an opportunity to align, only 10.5% of the fire perimeters aligned. It is clear that as more fires are available on the landscape, more fire interactions will occur until some saturation of the landscape exists. Roads, more common on the landscape than previous fire scars, were more often aligned with fire perimeters. Approximately 20% of fire perimeters aligned with roads, and another 1.7% of fire perimeters aligned with previous fire perimeters and roads together. Using fire perimeter and road data, we were able to explain 25.6% of all fire perimeters and 32.6% of fire perimeters in the population of fires that encountered previous fires.

In terms of fire severity, we found that on average, RdNBR values were lower with increasing times burned. However, the averages mask an important point: the subset of points that reburned had lower first-fire severity than all points on average. Thus, fire severity increased in almost as many points as it decreased in subsequent burns. The change in severity from one fire to the next varied by time since fire. On average, subsequent fire severity was less than previous fire severity when time since fire was less than six years. Absolute fire severity also tended to increase with time since fire.

Implications for Management and Policy

Implications of this research for management are that previous wildfires do sometimes act as fuel breaks or fuel reduction treatments for subsequent fires, even in the absence of roads. Since wildfires treat much more acreage than prescribed fire or thinning treatments in the southwestern United States, they need to play a role in the successful and safe management of wildfire. If the time between fire interactions is reduced (more frequent burning on the landscape) we will not only see more places where managers can use interactions to their benefit in controlling fire but we are likely to see a decrease in the severity of reburns. This bodes well for areas where managers are working to create a “jigsaw puzzle” of burns across the landscape. In these areas, previous fires, especially recent ones, are likely to be of use in stopping fires and also in mitigating subsequent fire intensity and severity. Assessing fires for whether they can be managed for multiple resource objectives could be partially based on whether other wildfires have burned in the area recently. Indeed, this is already done by many fire management programs. However, a better understanding of these interactions through additional case studies and broad landscape level analyses would be helpful.

Future Research and Data Needs

Fuel treatments such as prescribed fire or thinning may explain the locations of some fire perimeters, and if a good spatial database of those treatments is developed it would be valuable to repeat this analysis using that data and compare the efficacy of fuel treatments with previous wildfire in halting the spread of subsequent wildfire. In addition, further exploration of severity of reburns by vegetation types would be very informative. A better understanding of trends by vegetation type could prove valuable at both the landscape and site scale. Previous case studies have been successful using fire progression maps and weather data in helping to understand fire interactions and severity. Developing a repository of progression maps could help to further our understanding of fire behavior and effects on a regional scale.

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Appendix B: List of Scientific and Technical Publications and Science Delivery Products

Articles in peer-reviewed journals

Yocom, L.L., J. Jenness, P.Z. Fulé. In prep. Previous fires and roads limit wildfire growth in Arizona and New Mexico, U.S.A. Target journal: Forest Ecology and Management.

Yocom, L.L., J. Jenness, A.E. Thode, S. Mueller. In prep. Wildfire severity decreases in reburns in the southwestern United States. Target journal: International Journal of Wildland Fire.

Technical reports

Yocom, L.L. In prep. Fire interactions in the Southwest. Working Paper. Southwest Fire Science Consortium. Flagstaff, AZ.

Conference abstracts

Yocom, L.L. Wildfire as fuel treatment: Effects on subsequent fire size in the Southwest. Association for Fire Ecology International Congress, Nov. 17, 2015, San Antonio, TX.

Yocom, L.L., J. Jenness (presenter), P.Z. Fulé. 2017. Previous fires and roads limit wildfire growth in Arizona and New Mexico. Abstract submitted to 14th Biennial Conference of Science & Management on the Colorado Plateau & Southwest Region, Flagstaff, AZ.

Field tours

Yocom, L.L., A. Thode, and P.Z. Fulé (presenter). What happens when wildfire reburns an area? Field Trip presentation, Davis Mountains Reserve, The Livermore Summit: Ponderosa Pine Restoration in the Southwestern United States. June 15, 2017, Alpine TX. Figure 9.

Figure 9. Photo of Pete Fulé presenting results at a field trip during a summit on ponderosa pine restoration in the southwestern United States, Alpine, TX.

Website development

We developed a webpage for this project, where a brief description of the project can be found. We will also provide links to the final report and published manuscripts on this site. The web address is https://cmswork.nau.edu/SWFire/.

Webinars

Yocom, L.L. In prep. Fire interactions in the Southwest. Webinar for scientists and managers, Southwest Fire Science Consortium.